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Conducting Polymer Chemical and Humidity Nano Sensor

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ABSTRACT

Film casting technique was employed to deposit Polypyrrole (PPY), Polyaniline (Pani-EB) and their blend films on aluminum electrode and well cleaned glass plates for chemical and humidity sensing structure respectively. Pure aluminum (A1) was evaporated in a vacuum of $2.5x10^{-3}$ Pa from tungsten filament. The thicknesses of the PPY, Pani-EB and their blend films were measured by capacitance and weighing methods . The change in capacitance with frequency was used to sense the acetone and ammonia gas. The change in resistance with humidity percentage was measured in presence of humidity control chemical $CaC1_2.2H_2O$. Hygrometer (made in Germany) was used to measure the humidity percentage.

Keywords: Chemical sensor, Humidity Sensor, Capacitance, Resistance.

INTRODUCTION

Studies on conducting polymers like Polypyrrole (PPY), Polyaniline (Pani-EB) and their blend are interesting because of their high conductivity and stability. Polypyrrole has been extensively investigated because of its good environmental stability and ease of preparation. The electrical properties of polyaniline can be can be reversibly controlled both by changing the oxidation state of the main chain and by the protonation of the imine nitrogen atom. The electrical properties of polyaniline is improved when mixedwith polypyrrole. The blend of PPY and Pani-EB shows stable conductivity and improved processability (Suresh I Jain *et al*, Gyorgy Inzelt).

One of the simple methods to detect gases is by measuring the change in electrical capacitance or/and resistance induced by the adsorption of gas molecules on the surface of an organic semiconductor. Efforts have been made by many scientists to study the response of organic polymers to a number of gas molecules (Chul Park *et al*) and humidity sensors for water vapor measurements (Sergei V. Kornlov). In the present study an attempt has been made to study the sensing of ammonia gas by PPY, Pani-EB and their blend in thin film form. Also work has been extended for sensing acetone and humidity controlled chemical $CaC1_2.2H_2O$ by polypyrrole.

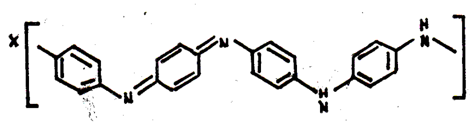
EXPERIMENTAL

Pure aluminium (Al) was evaporated in a vacuum $2.5x10^{-3}$ Pa from a tungsten filament to form bottom and top electrodes.

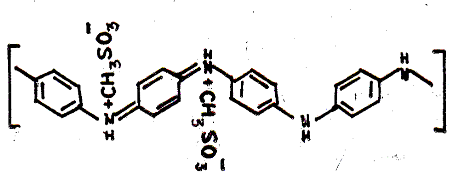
PPY film was deposited on well cleaned glass substrate from the solution of PPY dissolved in NMP solvent by solution casting technique to complete the Al-PPY-Al structure for sensing chemical gasses and Al –PPY structure for humidity sensing. The structure of the polyaniline, acid doped polyaniline and polypyrrole are shown in figure1. Thin Films are deposited on a substrate by controlled condensation of the individual atomic molecule or ionic species either directly by physical processors or by a chemical and electrochemical reaction. Since individual atomic molecule or a ionic species of matter may exist either in the vapour or in the liquid phase.

The thickness was measured by gravimetric and capacitance methods. The resistance and capacitance of the Pani, Acid Pani and PPY film was measured by using Hewlett Packard digital LCR–meter (4275A). Hygrometer (Made in Germany) was used to measure the humidity percentage. The schematic diagram of chemical sensor (capacitance configuration) and humidity sensor are given in figures. (2) & (3)

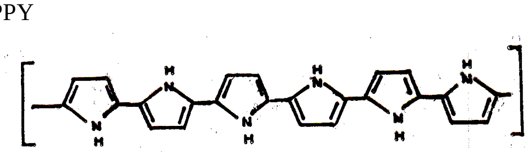
Pani-EB



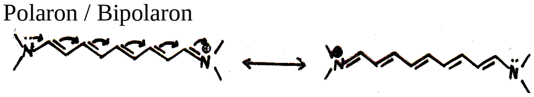
Acid-Pani



PPY



Polaron / Bipolaron



Conduction

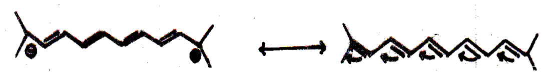
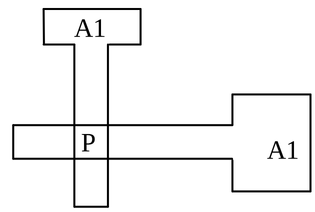
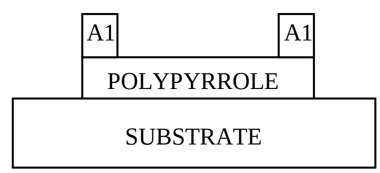


Figure 1. Structure of Pani-EB, Acid Pani and PPY conducting polymers and conduction mechanism.



P-Polypyrrole , Al- Aluminium
Figure. 2 Chemical Sensor



Al- ALUMINIUM
Figure.3 Humidity Sensor

RESULTS AND DISCUSSION

Figure. 4 shows the variation of capacitance with log frequency for the PPY film. In the figure curve 1 corresponds to the film to any gas the capacitance variation before exposing the film to any gas. Curve 2 shows the reading taken while the film is in ammonia atmosphere and curve 3 represents the values after the removal of ammonia atmosphere. It is seen that the film capacitance

suddenly increases when it is exposed to ammonia gas. At 10 kHz the capacitance values changes from 27 to 65 nF. After exposing the sample to atmospheric condition the sample almost regain its original capacitance value. For Pani -EB film (Fig.5), the value of capacitance changes from 0.88 pF to 160 pF. The Pani -EB film is not regaining its original capacitance value after exposure to atmospheric condition. A large increase of capacitance value is observed for PPY-Pani –EB blend film (Fig.6) exposed to ammonia gas. The value of capacitance changes from 2.7 pF to 780 pF. Like Pani-EB film PPY-Pani-EB blend also not regaining its initial capacitance value after the removal of ammonia atmospheric conditions. This behaviour indicates the influence of Pani-EB over PPY. The change of capacitance is caused by the change in charge carrier concentration due to the donor – acceptor states arising due to the gaseous adsorption. Generally electron donating gases such as ammonia, if adsorbed, have an opposite effect in that the carrier density will be reduced, Hence there is a increase in the value of capacitance (Jan. J. Miasik).

Figure 7 shows the capacitance versus log f plot for the PPY film exposed to acetone gas. In the lower frequency range the film capacitance suddenly increases when it is exposed to acetone gas. At 10 kHz the capacitance value changes from 35 to 180 nF. After exposing the sample to air atmosphere (to remove the gas) the sample regain its original capacitance value (35 nF). The change of capacitance caused by the change in charge carrier concentration due to the donor – Acceptor states arising from the gaseous adsorption. Figure 8 shows that the change in resistance with corresponding humidity percentage when $CaC1_2.2H_2O$.was used as a humidity controlling chemical.

From the figure it is observed that the resistance adsorbed and that are more oxidizing there by leading to a decrease in the total number of charge carriers or water molecules diffuse into the crystal lattice and adsorb on new sites, enabling the donating character of water molecules (electron pairs) to prevail. At 10 kHz the resistance increases almost linearly with increases of humidity percentage. Above 10 kHz the value of resistance slowly increases with increase of humidity percentage.

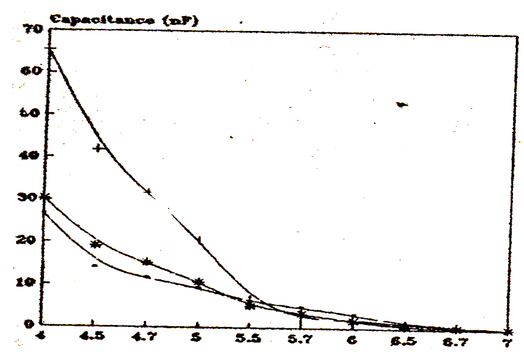


Figure 4 Capacitance versus Log f for PPY film exposed to ammonia gas

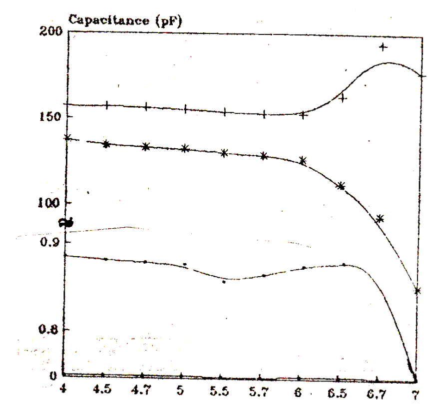


Figure 5 Capacitance versus Log f for Pani -EB film exposed to ammonia gas

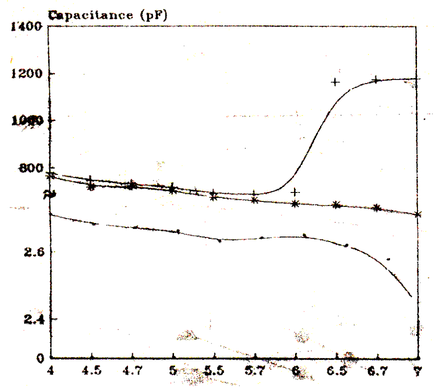


Figure 6 Capacitance versus Log f for PPY/Pani -EB film exposed to ammonia gas

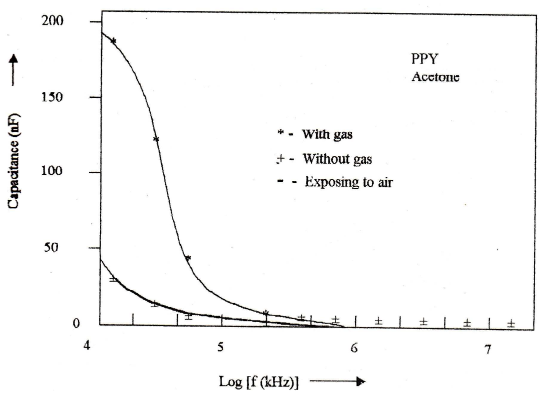


Figure. 7. Capacitance versus log for PPY film (d= 5.6 μm)

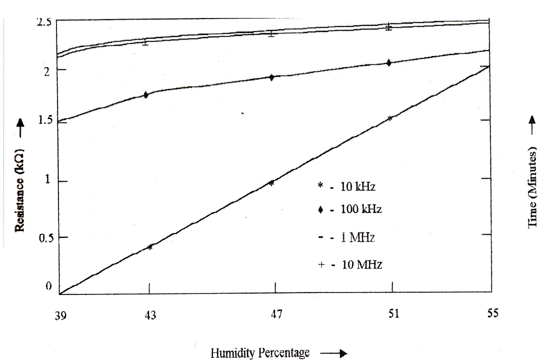


Figure 8. Humidity versus resistivity and time

CONCLUSION

It is concluded that that polypyrrole, polyaniline EB and their blend having good response to ammonia gas. Polyaniline –EB and Polypyrrole – Polyaniline –EB blend films are not regaining its original values, whereas polypyrrole regaining its original value when exposing to atmospheric conditions. So PPY can act as a good indisposible ammonia gas sensor, while polyaninilie-EB and Polypyrrole-Polyaniline –EB blend filmcan be used as disposable ammonia sensors.

Also from the above observations the polypyrrole films are very useful in sensing acetone gas. From the humidity studies ,it is observed that the resistance increases linearly with increase of humidity percentage for 10 kHz.

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